FY 98
RESEARCH
TECHNOLOGY AREA PLAN

AIR FORCE RESEARCH LABORATORY
WRIGHT-PATTERSON AFB OH

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About the cover: The Air Force Office of Scientific Research (AFOSR) is supporting research using supercomputers to understand and simulate turbulence. Supercomputer simulations are critical means of verifying designs for supersonic (cover photograph) and hypersonic aircraft, for which wind-tunnel testing is impossible. The simulation (performed by Professor Parviz Moin of Stanford University), in the area of supersonic aircraft design shows the sonic boom which is visible as a circle behind the vehicle. Photograph provided courtesy of Professor Antony Jameson, Stanford University. For additional information reference *Scientific American*, January 1997, Volume 276, No. 1, for article "Tackling Turbulence with Supercomputers."

RESEARCH

VISIONS AND OPPORTUNITIES

The mission of the Air Force Office of Scientific Research (AFOSR) is to sponsor and sustain Air Force relevant basic research to rapidly transfer and transition research results to current and future systems that support the Air Force global engagement strategy.

This vigorous, focused, and diversified basic research program provides our nation with the required depth and scope of options for new and advanced technologies to meet the air and space superiority goals of the Air Force. The rapid pace of change in the post-Cold War era necessitates a shifting emphasis in military technology investments, as the Scientific Advisory Board suggests in their New World Vistas (NWV) study. AFOSR has incorporated their recommendations as a guide in selecting new research initiatives. Furthermore, the relative decrease in planned acquisition of new weapon systems makes it even more important to build a closer partnership with the U.S. industrial base, logistics support and the operational Air Force. This partnership helps to keep the focus of basic research on the warfighter needs, near- and long-term, and provides a quick transition path to current and future systems.

The Air Force Office of Scientific Research has adopted the vision to build partnerships fostering excellence and relevance. Its key components are technology transition partnerships and laboratory partnerships. Their objective is to increase success and speed of technology transfer and transition while maintaining our long-standing tradition of quality research. Our partnership approach fosters integration among Air Force, university and industry researchers, operational Air Force and U.S. industry. Most importantly, it associates in-house basic (6.1) research at the Air Force Research Laboratory (AFRL) with the applied research (6.2) and advanced technology development (6.3) principal investigators within AFRL. Last year, more than 1,500 active research tasks produced more than 400 significant technology transitions to Air Force 6.2/6.3 programs, to U.S. industry and to other customers within and outside the DoD.

Of critical long-term importance to the Air Force are programs directed at enhancing our most precious resource-human talent. These programs focus on the development of new technical research talent and the introduction of existing talent to Air Force research interests. This includes provisions for undergraduate and graduate student research, fellowships for graduate students, and postdoctoral assignments at AFRL. In addition, university faculty are sponsored in summer programs as well as for sabbaticals at AFRL. Air Force researchers visit and work at highly respected laboratories in the U.S. and overseas as part of this program. We emphasize full participation of minorities and minority institutions in these efforts. Our interface with the international science and technology community through our offices in London, UK, and Tokyo, Japan allows the Air Force to leverage foreign research investments through access to, and in collaboration with, foreign laboratories and researchers.

This Technology Area Plan reflects AFOSR's commitment to preserve and strengthen the national knowledge base and research infrastructure in support of the Air Force goal of global engagement. We produce world-class, militarily significant and commercially viable technology advances; we leverage the Air Force science and technology investment; and we transition research results to users in the Air Force through U.S. industry.

This plan has been reviewed by the Air Force Laboratory commander and all directors, and it reflects integrated Air Force technology planning. Air Force basic research is integrated with other DoD basic research through the DoD Basic Research Plan. I request Air Force Acquisition Executive approval of the plan.

RICHARD R. PAUL
Major General, USAF
Technology Executive Officer

JOSEPH F. JANNI
Director
Air Force Office of Scientific Research

CONTENTS

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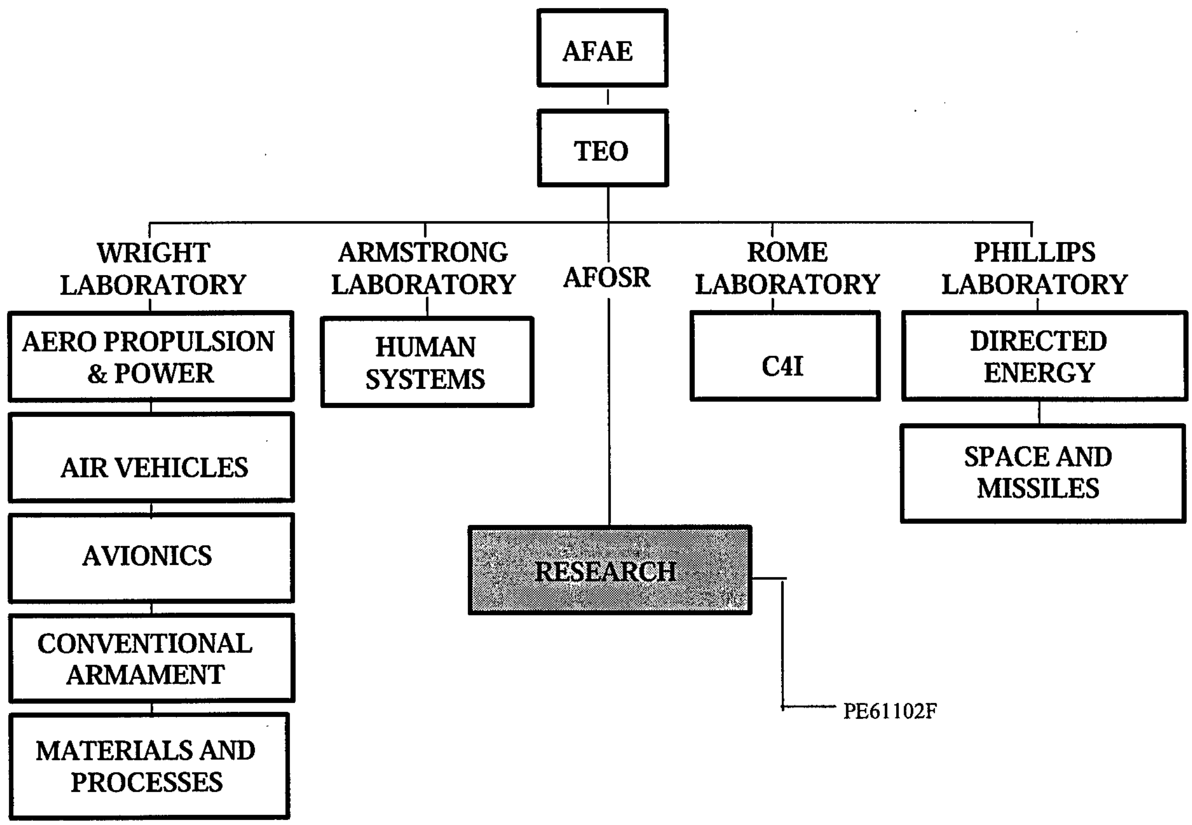


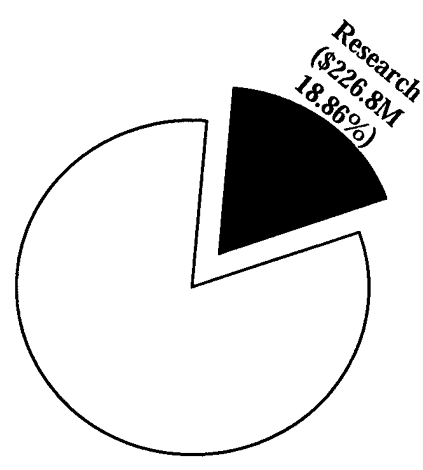
Figure 1. Air Force Science and Technology (S&T) Program Structure.

INTRODUCTION

BACKGROUND

The research technology area plan encompasses Air Force (AF) basic research. It includes all scientific and engineering disciplines contributing to the Air Force mission. The basic research outlined in this plan will enable the Air Force to perform its mission far into the 21st century. The research technology area goals are to:

- maintain technological superiority in the areas relevant to Air Force needs
- prevent technological surprise to our Nation and create it for our adversaries
- maintain a strong research infrastructure of universities, U.S. industry and the Air Force Research Laboratory (AFRL)
- complement the national research effort, and
- transfer research results to users and customers



Estimated AF S&T Budget for FY 1998: $1.203B

Figure 2. Research S&T vs. AF S&T.

With its proud tradition of over 40 years, the Air Force Office of Scientific Research (AFOSR) is charged with directing the Air Force's basic research program. Through grants to universities, contracts for industry research, and support for basic research at all AFRL locations, AFOSR forges the base of future Air Force strength. These research programs, funded at about $185.6 million for FY 97, consist of approximately 1168 extramural grants and contracts to about 450 academic institutions, industrial firms, and government laboratories, as well as about 120 intramural research efforts throughout AFRL.

Our support of basic research has not only served Air Force goals directly, but also contributed to a wide spectrum of scientific breakthroughs. During the past 40 years, the Air Force has provided basic research funds to more than 20 U.S. researchers who, as a result of the funded work, were later awarded Nobel Prizes.

AFOSR-sponsored research has led to many technology breakthroughs that have had immediate impact on the requirements of the warfighter. One example of these important contributions is a nickel aluminide alloy (NiAl) which was successfully tested for use in fabricating turbine vanes for the Joint Turbine Advanced Gas Generator (JTAGG) engine. NiAl is a potential replacement material for the nickel-based superalloys currently in use at temperatures in excess of 1200 degrees Celsius. Compared to nickel-based superalloys, NiAl intermetallic alloys weigh 30 percent less, provide better oxidation resistance, have four to eight times greater thermal conductivity, and will greatly enhance engine performance.

AFOSR has supported research development for engineering tools that will help to evaluate and improve the structural integrity of the Air Force's aging fleet of aircraft. A novel experimental method was developed that simulates operational fretting fatigue through the use of an accurate finite-element model that can calculate stress, strain and displacement fields induced by fretting. Results of this research will help engineers characterize aircraft materials wear during operational service.

Another recent achievement includes the development of new multi-color polymers that have potential use in Air Force fighter jet canopies. This technology will allow rapid control of brightness inside fighter cockpits during maneuvering above and below clouds, substantially prolonging the lifetime of cockpit display devices which will become viewable at much lower intensities than today's high intensity devices.

AFOSR-sponsored research has also led to the recent development of ultrasensitive sensors to detect minute quantities of water vapor and other gases. Airborne laser researchers at Phillips Laboratory and contractors are now using these sensors to improve the output power and efficiency of the Chemical Oxygen Iodine Laser (COIL), selected for use in the Airborne Laser demonstrator program. NASA is also using these sensors to measure mass flows for controlling the performance of jet engines.

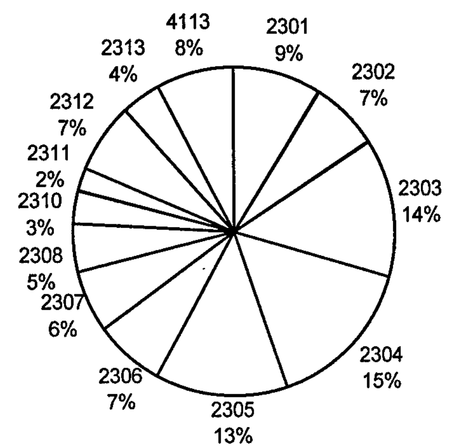
Finally, researchers at Rome Laboratory have developed several space-time adaptive processing (STAP) algorithms which significantly improve the detection performance of airborne phased array radars. These algorithms have significantly improved the performance when operating in non-homogeneous radar clutter environments. Peformance testing is currently being conducted with experimental airborne phased array radar.

The basic research program is divided into twelve scientific projects and one educational project. (Table 1) shows these project designations and titles.

Project	Title
2301	Physics
2302	Solid Mechanics and Structures
2303	Chemistry
2304	Mathematical and Computer Sciences
2305	Electronics
2306	Structural Materials
2307	Fluid Mechanics
2308	Propulsion
2310	Atmospheric Sciences
2311	Space Sciences
2312	Biological Sciences
2313	Human Performance
4113	Science and Engineering Education Programs

Table 1. AFOSR's Research Projects

The relative distribution of Air Force basic research funds for these projects is shown in Figure 3 based on the FY 98 President's Budget Request. The program described in this TAP is subject to change based on Congressional action. Other agencies such as the Defense Advanced Research Projects Agency (DARPA), the Ballistic Missile Defense Organization (BMDO), and the Office of the Secretary of Defense (OSD), provides AFOSR additional funds for basic research. These programs are fully integrated into the areas described in this TAP and ensure a broad scope and critical mass for Air Force basic research programs.



Estimated Research S&T Funding
for FY 1998: $226.8M

Figure 3. Major research thrusts (projects)

AFOSR has identified 15 Core Technologies of importance to the Air Force. AFOSR Core Technologies (Table 2) are defined as those technologies where AFOSR has made substantial investments and where AFOSR-sponsored research is critical, leading, or even dominant on a national scale. For each Core Technology, the scientific disciplines and research issues that need to be addressed to advance the core technology have been linked with the customers, users, and beneficiaries of the core technology. In view of the complexities (many disciplines, very different customers) and the nonlinear nature of these linkages (e.g., 6.1 often feeding directly into operations), the Core Technologies are the AFOSR basic research taxonomy for making management, priority and investment decisions. We believe that only technology advances, not just discipline advances, provide tangible customer benefits.

AFOSR Core Technologies

Structural Integrity
Structural Materials
Airbreathing Propulsion
Rocket and Space Propulsion
Aerodynamics and Hypersonics
Real Time Avionics
Optical Computing and Storage
Optical Countermeasures
Signatures and Surveillance
Precision Strike
High Power Microwaves
Space Weather Prediction
Hazard-Free Operations and Maintenance
Intelligent Systems for Selection and Training
Sustained Human Performance

Table 2. AFOSR Core Technologies

Thus, core Technologies represent AFOSR's approach to manage technology advances through coordinated research in several disciplines for the benefit of our customers, and represent road maps for basic research.

AFOSR works with the AFRL technical directorates and the AFRL to ensure research is integrated within the whole Air Force Science and Technology (S&T) program, and that it is responsive to current and future Air Force and Defense needs. AFOSR also works with the Office of the Director, Defense Research and Engineering (ODDR&E), other Services, Defense Advanced Research Projects Agency (DARPA), and the Ballistic Missile Defense Organization (BMDO), as well as other Federal agencies that sponsor research in technical areas of Air Force interest, to ensure that programs are coordinated, complementary, and leverage each other.

DEFENSE RESEARCH: The ODDR&E, other Services, DARPA, and BMDO jointly plan and coordinate the Defense Department's basic research efforts through the Defense Committee on Research (DCOR). As the Air Force's single manager for basic research, AFOSR is a member of the DCOR and ensures Air Force research is integrated with the remainder of Defense research. Joint Scientific Planning Groups (SPGs) are organized around the major defense science areas to ensure the integration of the Services' and agencies' research programs in these areas. Annually, as part of Defense research, AFOSR undergoes a DoD-wide Technology Area Review and Assessment (TARA) which provides feedback and guidance for AFOSR planning.

RESEARCH IN AIR FORCE LABORATORIES: Approximately one-third of our research program is conducted in-house by the Air Force Research Laboratory. These intramural basic research programs contribute significantly to the Air Force's, as well as the Nation's, research efforts. Twenty percent of the intramural research teams have been identified as leaders within the international community in fields of research. Through our concept of Laboratory Partnerships intramural efforts enable effective transition of research from extramural to the Air Force 6.2 and 6.3 science and technology programs, and to the system program offices, logistics, and test centers. In addition, intramural basic research attracts and retains world-class scientists and engineers. Thus, this intramural basic research investment provides the Air Force substantial benefits and leverage:

- World-class contributions to the Nation's research base.
- Talent pool for future Air Force technology leaders and managers.
- A training site for future scientific talent through high school, undergraduate, and graduate students.
- Interface with the national and international community through sponsorship of visiting scientists, guest professors, and workshops.
- Transition conduit for extramural research to the Air Force and its industrial suppliers from the national and international science and engineering communities.

In FY 98, the Air Force plans to increase research initiatives started in FY 97 and largely carried out in AFRL. The Third Millennium Initiatives (TMI) identified by AFRL are comprised of three components: Emphasis and Focus Areas, the Russian Initiative, and New World Vistas (NWV). The former two are conducted in the AFRL directorates, while NWV has both intramural and extramural research tasks.

Intense interaction between AFOSR's research program management and the S&T thrusts performed in AFRL assures relevance and timely response to Air Force needs. Formal feedback, generated during reviews in the fall and spring of each year, is used to determine the direction of our research, and to enhance the transition to DoD 6.2 and 6.3 efforts, as well as directly to U.S. industry.

RESEARCH IN INDUSTRY: Industry, especially the aerospace industry, coordinates with Air Force basic researchers in several ways.

Streamlining to compete in the global economy, U.S. companies have drastically cut research expenditures. Through information exchange Air Force-sponsored university researchers and AFRL now, more than ever, provide U.S. industry with access to new opportunities as well as with information helpful in addressing Air Force technology needs and opportunities. AFOSR maintains this relationship through workshop participation with industry and by providing U.S. industry access to our research results.

Instituted in FY 95 by the Director of AFOSR, the Partnerships for Research Excellence and Transition (PRET) was designed to sponsor research at colleges and universities that has immediate significance to the industrial community. This ongoing program is designed to broaden private sector support of research relevant to Air Force interests and to facilitate transition of Air Force related knowledge to the private sector.

In FY 97, about six percent of Air Force basic research funding directly supported basic research performed by U.S. industry. These efforts allow access to unique facilities, laboratory capabilities and special skills of industrial research teams. AFOSR's management of contracted research emphasizes corporate support through integration of research efforts into the contractors' planning process. This active approach to technology transfer stimulates interest in Independent Research and Development (IR&D) among firms with little or no research involvement and leverages industrial basic research programs that might otherwise not respond to long-term Air Force needs.

SMALL BUSINESS TECHNOLOGY TRANSFER (STTR): Beginning in FY 98, AFOSR will no longer participate in the SBIR program, and will concentrate solely on the STTR program. Our budget for STTR will increase from $3.24M in FY 97 to $6.0M in FY 98. However, AFOSR will continue to fund any Phase II SBIR projects approved in FY 97 and those in FY 98 resulting from the FY 97 Phase I awards. Like the SBIR program, the STTR program has two phases: Phase I is a 12-month effort for $100K and the Phase II program is a two-year effort for $500K. Unlike the SBIR program, the STTR program requires that small businesses applying for STTR award have a partnership with a research institution that participates in the project. This partner may be a non-profit research institution, a college or university, or an Federally Funding Research and Development Center (FFRDC). The decision to have AFOSR concentrate on the STTR program was made by HQ AFRL/XPXB because of the close contact between AFOSR Program Managers and private research institutions.

RESEARCH OVERSEAS: Today a large portion of research advances occur overseas, although the United States continues to lead the world. Since 1990, overseas inventors, mostly European and Japanese, have filed approximately 42 percent of all new U.S. patents.

To fulfill its mandate of assuring future technological superiority, the Air Force basic research program must respond to these developments and provide effective access to research advances overseas. To this end, AFOSR maintains foreign offices in London, UK, (the European Office of Aerospace Research and Development) and in Tokyo, Japan (the Asian Office of Aerospace Research and Development) which act as catalysts for increased cooperation in research and technology between AFRL directorates and foreign scientists. Both offices are staffed with senior researchers drawn from the Air Force S&T community. In addition to a number of liaison activities, the primary focus of these offices is collaboration and technology transition. Their customers, historically AFRL, increasingly include the logistics and test community and other Air Force and DoD agencies. Their means of fostering collaboration and technology transition include participation in the scientific and engineering communities of all nations at meetings, workshops, and seminars; detailed technical reporting, as well as analysis, and summary reports; and briefings and seminars at Air Force organizations. Special programs bring hundreds of eminent researchers from foreign laboratories to Air Force and DoD organizations for lectures, seminars, and other technical visits. A special program executes small, one-year "seed contracts" with foreign research institutes in technologies of particularly high interest to AFRL to form partnerships that will last beyond the individual contract. Another permits senior Air Force researchers to perform studies at leading foreign universities and laboratories. These latter programs provide access to advanced foreign techniques for AFRL efforts.

MINORITY PROGRAMS: The Historically Black Colleges and Universities and Minority Institutions (HBCU/MI) program continues to expand in FY 98. The Future Aerospace Science and Technology (FAST) Center program started in FY 95 as a five year initiative to develop first class research infrastructure at six selected HBCU/MIs, and is on track with several of these centers already contributing to the core AFOSR program. The FAST Centers at North Carolina A&T and the University of New Mexico have strong research programs and are participating actively in AFOSR's Program Manager portfolios. Our partnerships with NASA and DOE in assistance to Native American institutions continues and we are providing funding for several schools through these agencies. In FY 97 AFOSR participated in several OSD programs targeting HBCU/MI infrastructure and research capability. These programs resulted in grants to HBCU/MI in excess of $4M. We anticipate similar activity in FY 98.

CHANGES FROM LAST YEAR

Project 2301 - Physics. Photonic Physics was realigned to obtain greater efficiency and flexibility in supporting critical research topics and in reporting them. Plasma Physics has been restructured to examine novel alternatives for low observable technology, and high power microwave and laser physics for future directed energy weapons applications.

Project 2303 - Chemistry. Chemical Reactivity and Synthesis was eliminated due to a refocus of research in FY 98. Ongoing research in this area has been divided into four project subareas.

Project 2304 - Mathematical and Computer Sciences. Signal Processing, Probability, and Statistics was replaced by Signals Communication and Surveillance to more accurately reflect the subject concentrations and technology impact of research efforts.

Project 2305 - Electronics. Semiconductor Materials has been restructured to include Nonequilibrium Growth Techniques which include a broad range of techniques to grow otherwise unobtainable semiconductor alloys. Semiconductor Materials was restructured eliminating Ultrafast Laser Interaction, while adding Novel Alloys to include new research supported by AFOSR. The Joint Services Electronics Program is being phased out as a response to changing research needs and new patterns of research funding.

Project 2312 - Biological Sciences. Chronobiology and Neural Adaptation were restructured eliminating Biochemistry of Stress, Brain Mechanisms, and Neurobiology of Attention due to refocus in these areas. Biomimetic Sensors was created to explore novel sensors based on biological systems.

Project 2313 - Human Performance. Perception and Cognition, Team Resource Management subarea was added to include the cooperative nature of human decision making in Air Force systems.

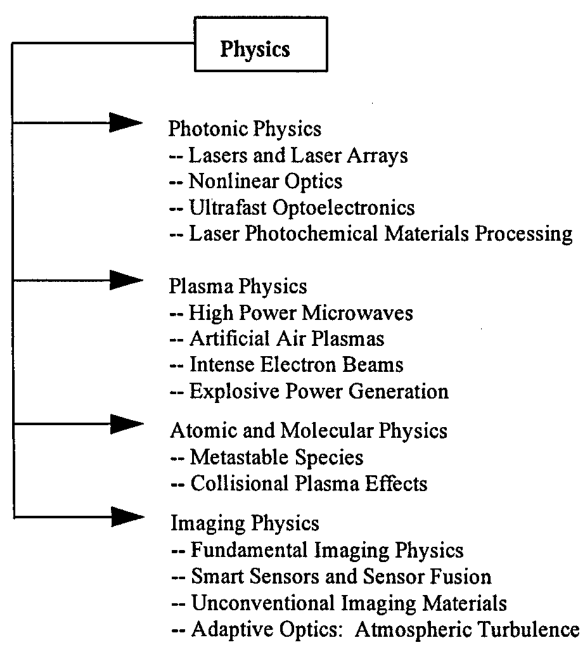
PROJECT DESCRIPTIONS

PROJECT 2301, PHYSICS

Physics research continues to establish the underlying science foundations of critical Air Force topics listed in New World Vistas, AFRL Emphasis and Focus Areas as well as in the DoD Strategic Research Objectives. It also establishes the basis for many additional technologies such as avionics, aerospace and propulsion. Research in physics has often found application in fields of electronics and related technologies: e.g., performance improvements of lasers have carried over into propulsion system diagnostics or atmospheric study tools; into industrial semiconductor processing or Air Force medical applications. While the users and customers may differ, fundamental principles underlying desired functionality are the same and require detailed understanding to model and predict performance goals. The physics program is jointly planned and executed within the three Services and is coordinated with DARPA. Results of these well integrated efforts have been transferred to industry. At a recent blind trial at Tinker AFB, a new portable instrument for nondestructive detection of subsurface corrosion, developed with AFOSR funding at Iowa State University, was cited as one of only two instruments having produced sufficiently reliable results on tests of KC-135 aircraft.

Photonic physics aims to study, devise, and make available lasers and laser arrays with characteristics needed in directed energy, optical information storage and display (large area and helmet mounted), wideband communication systems, manufacturing inspection systems, and in medical diagnostics. High power laser arrays and related optical components for threat countermeasures is a major application focus. The Fotofighter concept of the New World Vistas study provides a vision of this overall research area. Another major goal of this program is to devise nonlinear optical techniques and devices for high power laser beam delivery, automatic target tracking, and conversion of laser wavelengths to values required for countermeasures. Further major goals of this program are to advance electronic technology to speeds several orders of magnitude beyond what is available today, to create new source, diagnostic, and imaging technology at millimeter wave frequencies, and to create new beam processing technologies that can lead to dramatic advances in microelectronics and micromechanics. Customers for these programs are the Wright and Phillips Directorates of AFRL. Coordination with other services and DARPA is maintained by joint management, serving on joint review panel, and by joint funding. DARPA's Optoelectronic Materials Research Centers serve as major technology coordination and transfer mechanisms. These provide formal technology demonstrations and industrial collaborations for numerous results achieved by AFOSR funded research.

The plasma physics program seeks new knowledge about the complex phenomena surrounding the collective interactions of charged particles with each other and with electromagnetic fields. These phenomena are of critical importance to Air Force requirements in the areas of communications, radar, low observables, directed energy weapons, satellite control, hypersonic drag reduction, electronic warfare, chem/bio decontamination, and materials processing. A large portion of the current research program is dedicated toward the study of novel sources of high power microwave (HPM) radiation.



Theses efforts are closely orchestrated both with New World Vistas as well as with a five-year HPM Multidisciplinary University Research Initiative (MURI) sponsored by ODDR&E started in spring of 1995. This well-coordinated university/industry HPM research program is already feeding new discoveries and insights into the HPM development projects at Phillips Laboratory and the Army Research Laboratory; Rome Laboratory may reap benefits as well for AWACS applications. Building upon past seed investments in the area of microwave/plasma interactions, the plasma physics program has just launched a major new coordinated research program aimed at reducing the power budget necessary to sustain appreciable plasma densities in sea-level air. This program also coordinates with Wright Directorate, NWV and MURI efforts to bring the necessary critical mass of research talent to bear on the problem. If successful, significant impact is expected on hypersonic drag reduction, chem/bio decontamination, and other areas of major importance to Air Force warfighters.

Atomic and molecular physics research is directed toward understanding the interactions of atoms and molecules related to time and frequency physics and to upper atmosphere modeling. Accurate models of interatomic interactions will be used to make GPS clocks smaller and more accurate. Improved data and modeling capabilities will permit prediction of upper atmospheric processes affecting communications, surveillance, and remote sensing from space. This latter program has helped to establish reliable levels of background emission and demonstrate the imaging capability that is to be used in the Space and Missile Systems Center's (SMC) Defense Meteorological Satellite Program. Data on etchant species have been provided to revise industrial plasma reactor models (SEMATECH).

Research in imaging physics addresses the theoretical and experimental bottlenecks impeding the exploitation of advanced imaging technologies for the Joint Warfighter. Fundamental issues concerning the image formation and propagation processes are addressed. Physical and mathematical problems in image inversion/reconstruction, inverse scattering, and electromagnetic wave generation/propagation in various media are of interest. Distributed detector systems, multi-featured sensors, and multi-spectral methods are investigated with regards to smart processing and sensor fusion for global situational awareness. Providing real-time response to the battlefield commander evokes interest in integrated parallelization of devices, supporting software, and the chosen target recognition/feature extraction paradigm. Neural network imaging controllers, feature based statistical estimation methods, and the electronic emulation of biological vision systems are investigated to provide fast and accurate information as opposed to raw data to the battlefield commander. Novel unconventional imaging methods to optimally recover images in the presence of atmospheric turbulence are investigated for both active (non-illuminated) and passive (naturally illuminated) imaging systems.

PROJECT 2302, SOLID MECHANICS AND STRUCTURES

This project seeks to develop a fundamental understanding of the behavior of aerospace materials, structures, and supporting facilities, leading to the cost-effective development and safe, reliable operation of superior weapons and defensive systems. Research includes such diverse topics as the micromechanical design of advanced materials, modeling and simulation of the dynamic behavior of aircraft, missiles, earth penetrators, airfield pavements/facilities, and large space structures, and the technology integration for the performance and survivability enhancement of these systems.

The mechanics research sponsored in this project is closely coordinated with research performed under Project 2306, Structural Materials, which considers the materials science processing aspects of modern aerospace structural material systems, and Project 2307, Fluid Mechanics, which considers basic research issues associated with turbulence modeling and hypersonic flight.

Future aerospace engine and airframe structures will be composed of advanced, fibrous materials capable of extended operation in severe environments. Research in the mechanics of materials area seeks to understand the fundamental behavior of these material systems to facilitate the development of accurate design and life prediction methodologies. The development of these materials will allow the design of faster, more efficient aircraft and spacecraft. These advanced materials are also enabling technology for future Air Force initiatives such as hypersonic aircraft, which can potentially take off from conventional runways and achieve global orbit, and highly maneuverable uninhabited aerial vehicles (UAVs). Current project thrusts include understanding the fracture behavior and thermomechanical behavior of high temperature composite materials, such as ceramic-matrix composites, metal-matrix composites, carbon-carbon composites. Scientific issues include improved fiber/matrix interfaces, durable coating systems, and improved design methodology and life prediction systems based on material damage growth mechanisms. Results from this program are being used by Northrop-Grumman to understand matrix cracking and fiber/matrix interface failure in ceramic-matrix composites. AFOSR researchers are also studying innovative heterogeneous material systems, such as textile composites, functionally-graded materials and nanostructural materials as well as functional materials for smart structure applications.

Solid Mechanics and Structures

Mechanics of Materials
-- High Temperature Composite Materials
-- Fracture Behavior of Materials
-- Ceramic-Matrix Composites
-- Internal Damage Growth Mechanics

Particulate Mechanics
-- Effects of Microstructures
-- Constitutive Behavior of Particulate Systems
-- Shear Localization and Instability
-- Flow in Porous Media

Structural Mechanics
-- Mechanics of Deformation and Damage
-- Aeroelasticity System Behavior
-- Structure-Control Integration
-- Active Structures

The extended service life for many existing systems also requires further research to understand how materials and structures behave after very long periods of service. Factors such as corrosion and multiple-site damage serve to reduce the load-carrying capability of aging Air Force aircraft. This area seeks new methods of nondestructive evaluation (NDE) of these systems to detect internal cracking and/or corrosion in a quick and reliable manner, and to provide improved life prediction methodologies. Results from this research are being used by the Air Force Research Laboratory to understand the effects of corrosion and fatigue on the safety of aging aircraft structures, and engineers at the McDonnell Douglas Aircraft Company are using methods developed by researchers at Purdue University for analysis of bonded composite repairs on metallic airframe structures

The goal of the particulate and fluid mechanics research program is to develop a first principles understanding of the behavior of particulate systems and their interaction with the surrounding environment. The first principle thrust focuses on understanding the mechanical behavior of multiphase particulate systems. Particulate materials are defined as those that can be represented as an assemblage of physically discrete particles - either alone or in a matrix material having significantly different properties. Particulate materials of interest include soils, rock, concrete, asphalt, and engineered nanoparticles. The specific research objectives are to understand: 1) the influence of material microstructure on overall macroscopic constitutive behavior; 2) the constitutive behavior of multiphase (heterogeneous) particulate systems; 3) the localization and instability in particulate media, including their potential to flow and liquefy; 4) effects of material interfaces; 5) damage accumulation and penetration mechanics of geomaterials; 6) effects of new chemical compounds released into the subsurface environment; and 7) transmission and attenuation of electromagnetic and seismic waves in geomaterials.

Particulate mechanics research examines particulate systems with characteristic lengths that range from nanometers to meters. Efforts seek to obtain quantitative relationships to describe the fundamental mechanics governing the behavior of particulate systems, for example the behavior between individual constituents and between the aggregate assembly and the surrounding environment in response to an external load. Efforts involve multidisciplinary theoretical, analytical and/or experimental approaches from disciplines such as engineering mechanics, material science, physics and applied mathematics. Constitutive models that incorporate the microstructural behavior of these heterogeneous anisotropic multiphase discrete systems are theorized and experimentally demonstrated.

Particulate materials are ubiquitous, hence the research products from this program will have a scientific impact on a diverse range of end users. This research will provide a knowledge base from which analytical models can be developed to design and evaluate new material processing technologies, and hence, more affordable aerospace structural materials. Direct benefits to the military services include real-time subsurface target detection and damage assessment on the battle field, improved earth penetrators and precision guided munitions effectiveness, enhanced structural survivability and vulnerability and "smart" infrastructure supporting systems capable of surviving extreme blast loadings. Much of the technology supporting these needs has been based on empiricism. Therefore, the scientific contribution of this program will be a physically based understanding of the behavior of a range of materials and analysis techniques to predict their response to new loading regimes.

The focus of the structural mechanics program is to investigate fundamental structural principles over a broad length scale (i.e., nanometer to meter scale). At the high end of this scale, an understanding of the aero-structural and structural-acoustic behaviors of airframe, engine structures and launch vehicles is desired. Nonlinearities in these systems are traced to the interaction of fluids and structures, large amplitude vibration, system nonlinearity due to damping, and other phenomenon. This research is expected to provide engineering information on airframe failure from fluid flow disturbances and engine stall due to pressure variation. This research seeks to provide answers to many system operational issues. Examples include limit cycle oscillations and flutter on fixed-wing aircraft, engine compressor instability and turbine failure. Results of this research have been used by the Cessna Aircraft Company to predict the onset of flutter, understand post flutter behavior, and develop active flutter control techniques. Also, researchers in the universities are working with Air Force Research Laboratory and the Aeronautical Systems Center (ASC) on these operational problems.

Smart and composite structures research involves coupling nonlinear structural mechanics principles with advanced materials development, fluid mechanics, control theory, and sensor/actuator technology, such as smart materials and microelectromechanical systems (MEMS). This research will lead to the development and design of real-time monitoring and self-correction techniques for enhancing system performance. For example, intelligent materials and active structures are being developed which can continuously monitor damage formation and growth in current and future aerospace structures. Continuous shape control of aerodynamic surface may also be possible through a precise distribution of sensors and actuators.

The anisotropy, inhomogeneity, and damage characteristics of emerging structural material systems dictate the development of new solid mechanics and structural analysis principles critical for performance prediction and material synthesis. Traditional mechanics of materials principles do not capture the fundamentals that dictate the behavior of these advanced material systems. One aspect of the structural mechanics program is to expand the fundamental knowledge base to better understand the mechanics of deformation and damage of aerospace structures. For example, engineers at both NASA and Goodyear Tire Company are applying computational methodologies developed under this program to understand nonlinear deformation of aircraft tires that lead to excessive wear.

In summary, research in solid mechanics and structures is necessary for the design and operation of future Air Force weapon systems, as well as the continuing operation of existing systems, which are currently projected for use well beyond their original design lifetimes. Under the Reliance Agreement, the Air Force has the lead responsibility for the mechanics of high-temperature structural materials and particulate material systems and fixed-wing aeroelasticity. The Army has primary responsibility for research in impact/penetration mechanics, and rotary-wing aeroelasticity, while the Navy is the lead service in the mechanics of thick-section composites, structural acoustics, and hydroelasticity. Project 2302, then, provides the only direct DoD 6.1 mechanics and structures technology support to the design and operations of USAF aircraft, missiles, and spacecraft.

PROJECT 2303, CHEMISTRY

Research in chemistry fulfills current and projected requirements of two principal Air Force technologies: materials and energetics. This project provides the fundamental knowledge needed to meet the increasing demands for materials with advanced properties, affordable cost, and environmentally benign processing. Achieving the required material properties, such as strength, durability, toughness, service temperature and lifetime, spectral response, and corrosion resistance, increasingly requires control of structure and composition at small levels, sometimes approaching fewer than hundreds of atoms and molecules. Areas of emphasis in materials chemistry include properties and processing of polymers, corrosion resistance, friction and wear, and the chemical and biochemical transformations which aerospace materials undergo in the environment.

Chemistry

- Surface Science
  - -- Tribology
  - -- Chemical Sensors
  - -- Electrochemistry
  - -- Surface Chemistry
- Polymer Chemistry
  - -- Electronic and Optical Polymers
  - -- Polymer Blends and Copolymers
  - -- Liquid Crystals and Liquid Crystalline Polymers
  - -- Organic Nanostructures
  - -- Durable Aircraft Coatings
- Molecular Dynamics
  - -- Atmospheric Chemistry
  - -- Energetic Materials
  - -- Chemical Lasers
  - -- Interactive Dynamics
- Theoretical Chemistry
  - -- Molecular Structure and Properties
  - -- Reaction Dynamics

The technology of energetics seeks to control the conversion of one form of energy to another. Transformation of stored chemical energy finds application in propulsion, munitions, lasers, and as a source of signatures of aircraft and spacecraft. Advances in space propulsion and power are sought by developing materials with high energy density and controllable stability. The detection and surveillance of space systems are achieved through the understanding of the detailed light emitting chemical reactions in the exhaust plume in comparison with counterpart reactions of the background atmosphere.

The study of surfaces, adsorbed molecules, and surface phenomena on the atomic or molecular level defines the area called Surface Science. Surface phenomena includes chemical, optical, mechanical, magnetic and electrical properties at the surface. This program advances basic understanding necessary to improve Air Force operations. The program focuses on the fundamental chemistry of surfaces, thin films, and interfaces in materials, components and systems. Four areas of research are all linked through their interfacial approach to problems of interest to the Air Force. These four areas are Tribology, Chemical Sensors, Electrochemistry, and Surface Chemistry. The tribological processes section addresses friction and wear and its prevention by use of various lubrication systems (solid, liquid, or vapor) or hard coats. The program is interested in both the generated need for the lubricant and the resulting effect of the use of either protection system. The interfacial chemical sensor section is concerned with detection of species through surface site activation processes including both chemical and biological sensor schemes. The interfacial electrochemistry section is interested in the interfacial behavior of surfaces and surface processes involved in both protection systems and surface and intercalative modifications. Corrosion and lubrication processes using electrochemical techniques, as well as, modifications such as hard coats, metal deposition and intercalation for power generation are at the core of this effort. The surface chemistry section concentrates on the distinct study of surfaces at the nanometer scale which often have unique and different properties than macroscopic materials. The information derived from such studies will be used to generate new materials and applications for nanometer devices outside of the semiconductor arena; such as magnetic processes and alloys. In-house research is conducted at the AFRL in the areas of lubrication (solid, liquid, and vapor), inorganic polymer synthesis, and corrosion in aging aircraft.

Research in polymer chemistry seeks to provide a science base to create materials with new properties for Air Force applications. A better understanding of the material behavior will also lead to better utilization of these materials in a manner that will yield more durable and affordable systems. This research supports both functional applications such as photonics and electronics and structural applications such as aircraft and rocket components. The knowledge generated in this work is continuously transitioned into development programs of the Air Force Research Laboratory, DARPA and BMDO. A new area of research, durable coatings, is added to this program. The goal of this new area is to provide the basic sciences that will lead to a durable aircraft coating system with an undercoat of thirty years durability, and a top coat (mission coating) that will last for eight years. New material concepts and an in-depth understanding of the degradation mechanisms in aircraft coatings are being pursued under this program. The other areas of focus are; active electronic and optical polymers, polymer blends and copolymers, liquid crystals and liquid crystalline polymers, and organic nanostructures. Polymers with active electronics and optical properties are needed for many advanced Air Force applications in electronics and photonics. This area supports applications such as communications, signal processing and high information content displays. The polymer blends and copolymers program seeks to control the nano- to micro- scale phase separation and to study the influence of these phase separation morphologies on the electronic and mechanical properties of the polymer system. The liquid crystals and liquid crystalline polymers program addresses the self assembly behavior of these materials and their influence on the physical properties. The results of these two areas will not only be relevant to optical and electronic applications such as laser hardening and nonmechanical laser beam steering, but also to structural applications such as light weight aircraft and rocket components. The organic nanostructure research will advance the capability to create and manipulate nanostructures. These capabilities can be useful for applications such as high-density data storage and ultra-compact electronics.

Research in molecular dynamics and theoretical chemistry aims at developing predictive capabilities for chemical reactivity and energy transfer processes and controlling these processes on a detailed molecular level. These capabilities will improve aircraft and rocket propulsion system design, detection and control of signatures and exhausts from aerospace vehicles, energetic materials for propellants and explosives, high energy laser systems, and materials with novel properties tailored to meet Air Force requirements. The basic understanding developed here is transitioned to applied programs by close interactions between principal investigators, Air Force laboratory scientists, and representatives of industry. For example, the High Energy Density Matter (HEDM) program, run jointly with Propulsion Phillips Directorate, studies energy storage and stability of molecules in order to produce novel propellants for spacelift.

Theoretical chemistry research has saved time and research money by eliminating trial-and-error synthesis of proposed HEDM materials which lack promise. Novel propellant additives developed in this program are currently being tested in collaboration with industry. Studies of the dynamics of ion-molecule reactions, reactions of atmospheric species, energy transfer, and gas-surface interactions support efforts to improve our understanding of processes that produce radiant emissions in the atmosphere; affect communications, plumes, and signatures; affect supersonic and hypersonic flows and combustion processes; and degrade materials in space. Research results are transitioned to many areas including predictive codes for radar cross sections (RCS) (REACH), models of atmospheric radiance (FAUST, MODTRAN), spacecraft interactions (SOCRATES), and chemical lasers. Research on atmospheric heterogeneous chemistry is being performed in conjunction with, and in some cases jointly with Air Force Space and Missiles Center (SMC) to assess the atmospheric effects of solid rocket exhausts. Research on novel metal and ceramic cluster-based materials is pursuing unique materials with properties selected for operation in extreme aerospace environments. Efforts to develop and improve infrared chemical lasers for Air Force applications are carried out with the Air Force Research Laboratory and support the Airborne Laser SPO.

PROJECT 2304, MATHEMATICAL AND COMPUTER SCIENCES

This project provides advances in the mathematical and computer sciences that increase our capability to model, analyze, understand, and control complex systems and phenomena of Air Force interest and also increase our capability to utilize computing effectively. Requirements are ubiquitous throughout the Air Force as reliance on software and automation becomes widespread both in embedded applications, simulation and training, and for engineering design, and as requirements for increased systems performance drive us into more nonlinear and complex domains.

Our program in dynamics and control has the Tri-Services leadership role as well as a high level of national recognition. Research is leading to improved techniques in the design and analysis of new control systems with enhanced capabilities and performance. Applications include the development of robust feedback controllers for advanced high performance aircraft with new capabilities for battle damage mitigation, maneuverability and engine stall avoidance; the control of vibrations and the shape of large, flexible space structures; active control of wing camber using embedded smart sensors and actuators; and the control of combustion and fluid flow processes associated with aerospace vehicles.

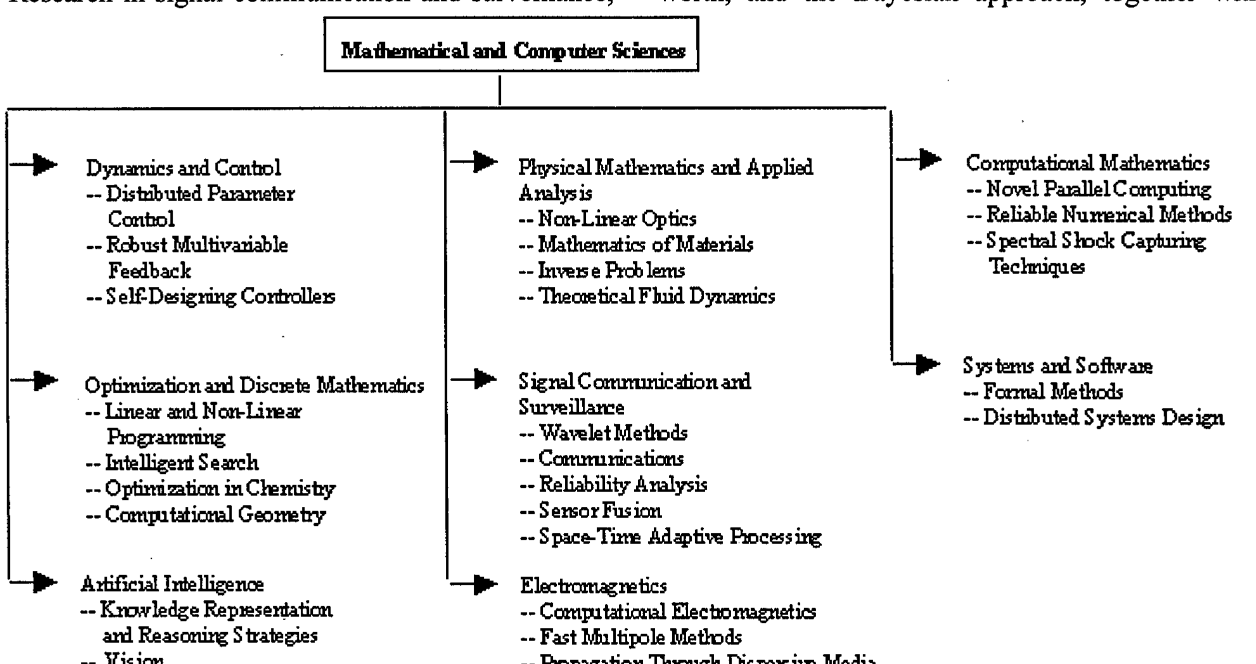
Research emphasizes distributed parameter control, robust multivariable feedback control, and adaptive control. Recently, novel interdisciplinary research has been initiated in nonlinear control to develop techniques for controlling fluid flow and combustion processes, as well as highly nonlinear coupled interactions between structural deformations and unsteady flows. Fundamental theoretical algorithms developed in this program have transitioned to Wright Laboratory as well as other industries and DoD laboratories.

Research in physical mathematics pursues the development and interrogation of accurate mathematical models (mostly nonlinear partial differential equations) in a diverse collection of areas of importance to the Air Force. These areas include nonlinear optics (an area of Tri-Service leadership), materials science, combustion/ detonation, and fluid dynamics. Equations describing electromagnetic wave propagation in nonlinear media are predicting stable operating regimes of semiconductor laser diode arrays. These lasers-on-a-chip can produce a substantial beam if properly orchestrated so that chaotic flickering and associated interference can be avoided. This work is in support of laser research at the Phillips Lab. Similarly, for mathematics of materials, the nonlinear variational problems whose minimal correspond to stable configurations of novel composite media and shape memory alloys have ushered in a new era in material descriptions and predictions and will lead to smart skins and other useful designer materials which are contemplated at Wright Lab. An example of theoretical fluid dynamics research which impacts the Air Force is the prediction of the dynamics of released stores from wings or bays during the higher transonic flight conditions at which the Air Force would like to operate. Such predictions would provide guidance for improved stores design and/or platform maneuvers since initial stores tumbling degrades final accuracy.

Research in computational mathematics develops improved mathematical methods and algorithms to support Air Force scientific computing interests. It focuses on innovative methods and algorithms which enable improved modeling, simulation, understanding and control of complex physical phenomena. These phenomena include compressible fluid flow, combustion and detonation, high energy-density materials, crystal growth, control of flexible space structures, plasma dynamics, directed energy weapons, and terrestrial as well as space weather. Research in this subarea also supports the national agenda in high-performance computing, including the exploitation of parallel computing. New and improved numerical techniques are being developed, including finite element and finite difference methods, essentially nonoscillatory methods, spectral methods, particle and vortex methods, homogenization techniques and continuation methods. Progress in nonlinear dynamical systems, wavelets and adaptive methods will enable development of new parallel multiresolution algorithms that yield accurate, extended time computations for dissipative systems of nonlinear partial differential equations. Research in multidisciplinary design optimization techniques, specifically in the areas of sensitivity equation methods and adjoint methods, will enable fast, reliable and efficient computational optimization, yielding improved system capability at lower cost.

Mathematical methods in optimization and discrete mathematics are directed toward the solution of large or complex problems such as those occurring in logistics, engineering design, or strategic planning. When applied to Air Force transportation systems, these techniques result in the more efficient movement of personnel and material. We are particularly interested in the development of innovative combinations of techniques from artificial intelligence and from operations research, and in the application of these techniques to military planning and scheduling problems. New efforts are underway in the control of discrete event dynamic systems. These systems are used to model both theater battle management and manufacturing operations. In the latter area, we expect to transition results directly to the manufacture of titanium aluminide rotor blades at Wright Laboratory.

Research in signal communication and surveillance, statistical theory, and in the treatment of transmitted information (signal processing) is pursued with the goal of improving communications, imaging, and the performance of systems. Among the new mathematical approaches that have been beneficial in communications (for identifying features in covert signals and compression of data in terrain-following links), and imaging (target recognition, advanced beam forming) are the wavelet transform and its generalizations. AFOSR has sustained an early lead in Federal and world levels in this technology. Nonlinear science is also producing an impact with chaotic systems that generate covert signals, and in the design of robust inexpensive analog to digital converters. Important progress has been made in extending imaging capability to a wide spectral range, including Synthetic Aperture Radar (SAR) and millimeter wave, as well as the use of multiresolution methods for modeling background, terrain (which helps one quickly spot moving vehicles). Combined sensing (such as laser-radar/FLIR) necessitates advanced statistical methods ("sensor fusion") for their rapid interpretation, critical to maintaining an edge in air combat. The integrity of mechanical/electronic systems and people-based organizations can be assured only through testing and statistics. Research on new multichannel space-time adaptive processing at Rome Lab has led to significant detection performance improvements for airborne phased array radars. New methodologies in reliability analysis are continuing to prove their worth, and the Bayesian approach, together with



algebraic experimental design, makes it possible to get the most for every dollar spent on life testing of critical systems. Air Force Operational Test and Evaluation Center (AFOTEC), responsible for the certification of reliable Air Force systems, has been implementing significant findings from research in this area.

Research in computer software and systems is directed toward developing advanced computing technology to support future Air Force needs in battlespace information management. One aspect of this research involves the control and integration of the vast amounts of information flowing through battlespace computer networks. This program has Tri-Service leadership in distributed computing for C^3I; one example of progress in this area is the creation of improved fault-tolerant distributed protocols. Breakthrough results in software agents provide new opportunities in this area. Distributed agents are envisioned for use in network management; for information retrieval, filtering, and summarizing; and for planning. Protection of these valuable network resources is another important area of research. New approaches for determining and analyzing network security properties at all network layers are expected, as well as means for examining how to ensure that a network possesses these properties. For distributed agents, it will be necessary to ensure that agents are not adversely affected by malicious hosts they might visit. Another important protection focus is anticipating the nature of future information system attacks and determining how they might be prevented. Finally, the complexities inherent in battlespace information management will require mathematical approaches for the specification, design, and analysis of distributed software systems. Rigorous formal methods that address important system properties such as timing, control, dependability, and security, will be especially crucial.

Artificial intelligence research is pursued to enable the timely management of information and to enable decision making based on that information. The key issue that we are addressing is how to effectively incorporate all available information, from diverse sources and modalities, into the decision process. To understand this issue, we are sponsoring research that looks for ways to make the best use of uncertain information, share and disseminate information, increase accuracy, speed, and economy of the recognition and identification process, and aid the intelligence analyst. The program concentrates on research needed to develop large-scale intelligent systems that can address practical Air Force needs. To that end we seek means to scale up those methods that work for small knowledge-based systems. We need to overcome present limitations in the amount of knowledge employed due to knowledge acquisition and management deficiencies. Present limitations on meaningful systems adaptation and improvement with use also needs to be overcome. Formalisms need to be developed for the representation of and reasoning with uncertainty, handling corrupt information, and effectively utilizing experiences. To aid the information analyst in fusing information from a diverse modality of sources, we seek means to combine numeric and symbolic inference methods. We seek ways to integrate probabilistic reasoning methods with traditional formal logic methods, and perhaps with other forms of computation. Qualitative methods which will drastically simplify computation and increase performance robustness are also of interest. We are seeking to develop technology that will provide support to decision making. To that end, research is needed to develop intelligent agents capable of gathering information, reducing data to manageable amount of essential information, and cooperating with other agents to solve problems. Research is also needed to combine artificial intelligence methods with operations research tools to overcome inefficiencies in solving some mission critical Air Force problems such as scheduling in a distributed, dynamic environment. The vision and image-understanding research within this program concentrates on solving those problems that interfere with the building of robust, accurate and timely recognition systems. Research is directed toward the development of context-based image-databases needed by the Air Force for time-critical and resource-bound operating conditions. The research is also directed toward applications such as surveillance, object recognition, target identification, cartography, scene interpretation from image streams, and the fusion of multi-sensor inputs. Research in object and scene interpretation from sensors using the visual, infrared, and radio frequency bands of the electromagnetic spectrum includes context-based, geometric-model-based, deformable-model-based, and physics-based approaches and the application of theories of invariants. Intelligent tutoring is an area of increased interest to the Air Force. The focus of this effort is to develop efficient computer mediated tools for instructional delivery both for training and tutoring with the objective of reducing manpower needs and optimize tutoring and training. Adaptive teaching systems which model the trainee, and attempt to understand his responses by simulating these models, is one area supported within this program. Research tasks in intelligent tutoring are linked to the Human Resources Directorate of the Armstrong Laboratory for the portion of effort which involves evaluation and experimentation with actual trainees.

Electromagnetics research ensures effective exploitation of electromagnetic waves and devices. Propagation studies emphasize characterization of inhomogeneous, turbulent, and/or dispersive media together with a description of the behavior of waves in such media. Results here would be supportive of the Air Force's interest in the Airborne Laser (ABL) as well as automatic target recognition (ATR) and high power microwaves (HPM), both of which anticipate exploiting wide-band sources. The investment in electromagnetic scattering prediction is driven by Air Force requirements in target acquisition, detection avoidance, and optimal on-platform source/receiver operation/placement. In the area of computational electromagnetics (CEM), large scale scattering computation is necessary for appraisal of radar coverage (theirs and ours) as well as prediction of radar cross sections for design or identification purposes. Research in CEM includes improvements in high-frequency codes as well as time-domain codes and all such codes must be accompanied by rigorous error control.

PROJECT 2305, ELECTRONICS

Research in electronics supports a broad community of high technology customers in the fields of surveillance, communication and precision weapons. It provides the fundamental basis for improving or developing future generations of Air Force electronic systems consistent with the SAB New World Vistas Topics, the AFRL Emphases and the DoD Strategic Research Objectives. Specifically, goals of this program are to use the entire electromagnetic spectrum for improving transmission bandwidth and data storage; to increase data and information processing speed in semiconductor, photonic, and superconducting systems for faster decision making; and to firmly control complexity, reliability and affordability. Intramural research in this program is carried out to a substantial part at the Phillips, Rome, and Wright Laboratories, and aims at the discovery of innovative design options. Research results are transitioned to the user community in the Air Force or to industry under Air Force contract.

Research in electronic devices concentrates on approaches which promise one or more of the following: greater frequency/speed of operation, greater bandwidth, lower power consumption, lower noise, higher rf power output, and greater reliability in support of Air Force needs in guidance, surveillance, communications, electronic countermeasures, and electronic warfare. These approaches fall into two categories: the application of new semiconductor materials to existing electronic devices, and the development of entirely new devices and material concepts.

The focus of electronic components and circuits is the development of new and improved materials and components supporting such advanced Air Force systems as millimeter circuits and IR imaging systems. Important drivers are higher frequency of operation, higher power output, the integration into monolithic integrated circuits and improved reliability.

Optoelectronic information processing research pursues the insertion of optical and optoelectronic techniques into information processing systems, the capabilities which range from parallel computing and image processing to signal processing. It supports device physics investigations that provide both the optical-electronic interface and the optical-environmental interface. Optical and optoelectronic devices perform data acquisition, transmission, interconnect switching, and memory functions and support efforts in the use of photonics to achieve real-time adaptive signal and image processing capabilities.

Electronics

- Electronic Devices
  - -- Femtosecond Processes in Semiconductors
  - -- Novel Transistor Concepts
- Semiconductor Materials
  - -- Non-Equilibrium Growth Techniques
  - -- Wide Bandgap Materials
  - -- Novel Alloys
- Electronic Components and Circuits
  - -- MMWave Components and Circuits
  - -- Spatial and Spectral Modulation
  - -- Far-IR Imaging Systems
- Electromagnetic Materials
  - -- Crystalline Non-Linear Materials
  - -- Optoelectronic Materials
  - -- Detector Materials
- Optoelectronic Information Processing
  - -- Optical Storage Approaches
  - -- Optoelectronic Computation and Interconnects
  - -- Spectral Techniques for Memory and Communication
- Quantum Electronic Solids
  - -- Superconducting Materials
  - -- Superconducting Magnetometry
  - -- Superconducting Electronics

Research in semiconductor materials is directed toward developing advanced electronic and optoelectronic materials with emphasis on growth and characterization of novel semiconductor compounds and heterostructures, radiation interactions, and reliability problems associated with solid state devices. Efforts will develop new materials for equilibrium and non-equilibrium growth techniques for structures with applications in digital and microwave devices; high temperature electronics; ultraviolet to infrared detectors; solid-state and semiconductor lasers; waveguides; and displays and emitters. The major theme includes an atomistic, solid-state physics based understanding of the materials science associated with such topics as heteroepitaxy, growth, and defects.

Work on electromagnetic materials focuses on interactions of light with semiconductors. Crystalline nonlinear materials and modulation materials are of interest. Bulk crystal growth techniques continue to be developed. Semiconductor material research is aimed at optoelectronics (especially infrared) with emphasis on use in fast, efficient electromagnetic applications such as in space and global communications, command, and control.

The major thrust in quantum electronic solids is to create new superconducting and other electronic material structures to enhance the ability to sense and manipulate observable information. The great virtue of superconducting electronics is that it can carry out the necessary functions faster, more sensitively, and with lower power dissipation--features which allow higher density of processing elements for a smaller instrument package. An adjunct to this program is the discovery of improved techniques for the nondestructive evaluation of aging aircraft.

PROJECT 2306, STRUCTURAL MATERIALS

This research provides the basic knowledge for development of new materials to improve the performance, life-cycle cost, and reliability of Air Force systems. Direct goals of this program are to supply advanced materials that will increase the thrust-to-weight ratios of engines, reduce the weight of aerospace vehicle structures while increasing their performance and control, and eliminate advanced materials reliability issues. Emphasis is on monolithic metals, intermetallics and ceramics; composites including matrices of metal, intermetallic, ceramic, and organic materials; and carbon-carbon materials. This program studies a broad range of material properties such as strength, toughness, fatigue resistance, and environmental resistance in airframe, turbine engine, and spacecraft applications. Research on processing methods is an integral component to the research on materials properties. This project directly supports the technology goals of the WL Materials Directorate. Extramural researchers closely coordinate with the four research tasks at this directorate and one research task at the PL Propulsion Directorate. The efforts in this project are also related to research being performed in

Project 2302, Solid Mechanics and Structures. Close coordination of this project with the entire DoD basic research program in structural materials is being maintained with all DoD services. Several jointly sponsored programs have resulted from this coordination process. Additionally, close coordination is maintained with industry R&D counterparts including Dow Corning, McDonnell Douglas, Rockwell, General Electric, and United Technologies.

The goal of the research thrust in metallic structural materials is to provide the fundamental knowledge required for new metallic alloys and composites for aerospace applications. Potential applications of these materials will include turbine airfoils and disks, engine casings and nozzle components, air-frame structural components, space and rocket propulsion components, and hypersonic vehicle skins. Improved metallic structural materials will be capable of higher operating temperatures and/or significantly reduced densities than currently available materials. These characteristics will result in increased thrust-to-weight ratios in gas turbine engines, lighter weight airframes, and will enable hypersonic vehicle technology. This includes development of materials to withstand temperatures up to and beyond 2400° F for turbine engines and hypersonic vehicle applications. This will be accomplished through an understanding of relationships between processing, chemistry, structure and properties of metallic materials. Specific scientific topics include the development and experimental verification of theoretical and computational (atomistic) models, phase transformations, interfacial phenomena, strengthening mechanisms, plasticity, creep, fatigue, environmental effects, and the dynamic and static fracture of structural metallic materials. Materials under research in the metallic structural materials thrust include lightweight alloys, refractory metals, intermetallic alloys, understanding the basic phenomena of deformation and design of bulk metallic glass alloys.

The objective of the ceramic materials research thrust is to provide scientific framework for current and future applications of ceramics, ceramic-matrix composites, and carbon-based materials in Air Force systems. Ceramic materials are attractive for Air Force structural applications due to their capability

Structural Materials

- Metallic Structural Materials
  - Metallic Alloys used in Aerospace Applications
  - Alloy Theory, Design and Experimental Verification
  - Laminated Metallic Materials
  - Processing of Metallic Materials
- Ceramics and Non-Metallic Structural Materials
  - Related Processing, Structures and Properties
  - Interface Control for Ceramic Matrix Composites
  - Fundamentals of Fracture and Creep
  - Oxidative Processes of Carbon-Carbon Materials
- Organic Matrix Composites
  - Environmental Effects on Polymer Matrix Composites
  - Processing Science of Organic Matrix Composites
  - Environmentally Safe Processing of Composites
  - Processing of Polymer Precursors

to work at very high temperatures, their intense strength and stiffness, their hardness and excellent wear properties. Introduction of ceramic bearings in gas turbine engines and Ceramic Matrix Composites (CMC) for exhaust nozzles should lead to major improvements in thrust-to-weight ratio, efficiency, and signature characteristics of engines. In support of these applications, this program emphasizes fundamental studies of high temperature properties of ceramic materials and their relationship to the atomic structure of constituting phases and to microstructure of the materials. Of particular importance are studies of oxide materials with large complex unit cells giving rise to high creep resistance. Detailed studies of interfaces and interphases, their atomic structure, thermodynamic and mechanical characteristics, and their influence on the creep properties of ceramics are also major components of this program. Currently, the research effort in interfaces concentrates on control of interfaces between the fiber and matrix in ceramic matrix composites. The goal is to lay the foundation for the development of tough, reliable ceramic matrix composites capable of working at temperatures above 2700°F. A variety of techniques for controlling oxidation resistance, thermal stability, and shear strength of interfaces are currently under investigation. In the area of carbon-carbon composites the program concentrates on designing new approaches for oxidation protection, such as protective ceramic films, oxidation-inhibiting dopants, and surface modifiers.

The goal of research in organic matrix composites is to provide the knowledge for lowering the life-cycle cost of using polymer matrix composites in Air Force systems. Additionally, improving the performance properties of these materials such as higher operating temperatures and improved compressive strengths after impact are important objectives. High temperature adhesives and processing of polymer precursors for carbon-carbon and ceramic structures are of interest to this program. The current program focuses on studying the durability of organic matrix composites exposed to ambient and harsh environment. Research will achieve a better understanding of the mechanisms of property degradation in polymer matrix composites caused by the environments. This knowledge is important to implementation of effective countermeasures during processing and deployment to prevent or decelerate performance degradation, and in reliably and accurately predicting the service lives of composite structures. The chemical and physical changes of the matrices, fibers and their interfaces will be investigated individually and collectively in a composite configuration to provide a better understanding of their influence on the property changes of composite structures.

PROJECT 2307, FLUID MECHANICS

Air Force basic research in fluid mechanics seeks to enhance the performance and reliability of aerospace vehicles by developing new capabilities for predicting and controlling the fluid dynamic and thermodynamic behavior of complex flows in flight regimes and propulsion systems affecting Air Force operations. This research seeks to understand key physical phenomena, to develop methods and models to predict them, and to create innovative strategies to expand the boundaries of flight by controlling these phenomena.

Major thrusts include: 1) the development of computational methods for accurate and efficient numerical solution of the equations of fluid dynamics, especially for dynamic, unsteady, multi-body problems, 2) active flow control relevant to engine nozzle exhaust flows, mixing thrust vectoring, and high lift, 3) the aerothermodynamics of hypersonic flows, 4) the fundamental structure and dynamics of transitional and turbulent compressible flows, 5) the prediction and control of turbulence, and 6) the complex internal aerodynamics and thermodynamics of flows in gas turbine engines. These efforts are closely coupled with Air Force Laboratory 6.2 and 6.3 programs, primarily at the Wright Laboratory. This project provides fundamental knowledge, data, concepts and tools for aerodynamic and aerothermodynamic prediction, design, test, and support. It directly supports the research needs of industry as well as the Air Force Research Laboratory, AF Test Centers and Logistics Centers.

Aircraft manufacturers, AFRL directorates and test centers require improved, validated turbulence models. In fact, such models top the list of industry needs for fluid mechanics research and are a key pacing item for computational fluid dynamics. Research targets the high Reynolds number, compressible flows of interest to the Air Force, and seeks to develop large-eddy simulation (LES) methods and improved subgrid turbulence models for accurate predictions

Aircraft and weapon systems in maneuvering combat operate in environments far more hostile than those occurring under level flight. Weapons released in this environment have been known to hit the launch aircraft. Advanced Computational Fluid

Fluid Mechanics

External Aerodynamics and Hypersonics
-- Compressible Turbulence
-- Advanced Computational Fluid Dynamics
-- Hypersonics, Viscous Flows and Real Gas Effects
-- Fluid Structure Interactions, Buffet, and Flutter
-- Inlet Distortions and Compressibility Effects

Turbulence and Internal Flows
-- Active Flow Control for Jet Vectoring, Mixing, High-Lift and Drag Reduction
-- MEMS-based Sensors, Actuators, and Systems for Flow Control
-- Unsteady Aerodynamics and Flight Controls
-- Compressor Instabilities, Forced Response and High-Cycle Fatigue
-- Turbulent Heat Transfer and Turbine Cooling
-- Turbulence Modeling, Mixing and Transport

Dynamics (CFD) research is developing numerical simulation methods which predict the dynamic motion effects on aircraft systems and missiles. Research in multi-body CFD is developing computer simulation technology which can predict the trajectories of weapons as they release from an aircraft, reducing the danger to pilots who fly weapons certification tests. CFD research also focuses on understanding the fundamental causes of inlet unstart, the sudden shut down of engines on maneuvering supersonic and hypersonic vehicles. Results in advanced grid generation methods from research at Mississippi State University are now being used by McDonnell Douglas Aerospace in the F-15 program.

Active flow control research explores fundamental flow instabilities and their control for potential application to thrust vectoring, engine controls, high lift, aero-optics, low noise, and several other critical areas. Low observable requirements fix jet nozzle exit geometry and require internal flow adjustments to optimize performance. Fluidic flow controls are being explored in this context. Innovative active flow control approaches also enable the development of advanced high-lift technologies for enhanced aerodynamic performance of stealth vehicle configurations. Active flow control may also alleviate currently uncontrolled sonic fatigue problems with the divergent nozzle flaps; those on the F-110 engine create one of the major headaches for logistics support of the F-16. Also, inadequate turbulent drag reduction strategies limit the potential for enhanced range and payload. Basic research approaches under exploration include innovative uses of microelectromechanical systems (MEMS) and neural networks, the generic issue being the management and control of vorticity production on aerodynamic surfaces. McDonnell Douglas is now exploring basic research results on jet control for supersonic jet noise reduction, fluidically controlled thrust vectoring, and paint removal processes. Boeing is exploring new aerodynamic testing methods based on recent basic research on microfabricated flow sensors.

Future hypersonic flight vehicles will operate at very high altitudes within the earth's atmosphere to reach global targets. At these altitudes the atmosphere is highly rarefied, and it is important to predict the character of these rarefied flows. Underpredicted drag and heat transfer can result in vehicles that will not reach their intended targets. Computational and experimental research aims at revealing the fundamental fluid mechanical properties of hypersonic, chemically reacting flow, providing better predictions of vehicle heating, directly leading to safe designs.

Maneuvering combat aircraft generate complex, 3-D spatially and temporally varying flows which are ingested by the propulsion system's airbreathing engine inlets. The total pressure distribution of these complex flows entering the inlets become even more non-uniform, or distorted, as the flow passes through the inlet compression shock wave system. This distortion greatly reduces the total pressure of the flow which enters the compressor face for supersonic propulsion and turbomachine engine propulsion systems. The greater the distortion, the lower the engine thrust. Computational fluid dynamic research has been undertaken to predict the complex distortion fields which arise in supersonic and hypersonic air breathing engine inlets and inlet systems on maneuvering Air Force aircraft and missile weapons systems.

Current flight control systems intentionally limit the operational envelope of modern fighters to avoid entering the post stall environment during dynamic maneuvers. Unsteady aerodynamics research within this project seeks to develop the knowledge base to expand the predictability and controllability of flows in this environment. Another critical need is preventing the unsteady aerodynamic buffeting of vertical control surfaces on the F-15 and F-16 which leads to structural fatigue, loss of reliability and degraded supportability.

A major concern of engine manufacturers, and the focus of the Integrated High Performance Turbine Engine Technology (IHPTET) Program is to improve the thrust to weight ratio of gas turbine engines. Improved compressor efficiency and stability are key elements of this requirement. Problems with heat transfer in the combustor and turbine stages account for half the ten-year development time currently required for new engines. In addition, thermally induced fatigue failures in the F-110 combustor produce one of the largest maintenance problems for the F-16. Research within this project aims at improving our understanding of heat transfer in high turbulence environments, improving film cooling, and controlling the unsteady fluid dynamics dominating compressor performance and contributing to the problem of high-cycle fatigue.

Through Joint DoD Cooperation, this research program is closely coordinated with Army and Navy programs. AFOSR fluid mechanics research focuses on central Air Force interests in high speed flows, compressibility, dynamic maneuverability, control of aerodynamic phenomena, and the fluid mechanics and thermodynamics of flow in gas turbine engines. In turn, the Navy focuses on hydrodynamic wakes and free surface phenomena. In the area of unsteady aerodynamics, the Army deals primarily with 2-D blade-rotor interactions relevant to helicopters, while the Air Force focuses on 3-D vortex dominated fluid-structure interactions relevant to aircraft maneuverability.

PROJECT 2308, PROPULSION

The space power and propulsion project conducts research applicable to all military air and space vehicular systems, including aircraft, tactical and strategic missiles, space launch vehicles, space vehicles, and future hypersonic systems. Advances in propulsion and energy conversion technology are essential to the increase in range, payload, speed, stealth, and supportability and decreases in cost of either existing or new vehicular systems. The payoffs include a 100 percent increase in range/payload for attack aircraft, a Mach 3+ capability in F-15 size aircraft, a 200 percent increase in payload to geosynchronous earth orbit, plasma propulsion systems for small satellites less than 250 kg., microthrusters for pointing concepts and optimization of collateral satellite systems, and ramjet/scramjet operation to Mach 8-10 using hydrocarbon fuels.

Research falls into the areas of chemically reacting flow, non-chemical energetics, and diagnostics. The research effort is being conducted extramurally by both universities and industrial laboratories, such as those of United Technologies Corporation, McDonnell Douglas Corporation, and the General Electric Corporation and intramurally at Air Force Research Laboratory. Chemically reacting flows involve complex coupling between the rate of energy release through chemical reaction and the fluid processes which transport fuel, oxidizer, combustion products, and enthalpy. Non-chemical energetic systems include plasma propulsion for efficient, orbit-correction, maneuvering, and orbit-raising space missions. Diagnostics research provides critically needed measurement capability for developing fundamental understanding and performance characterization of these processes such as spray and solid propellant combustion and plasma propulsion. For example, recent successes applying multiplexed diode spectroscopy to measure temperature and chemical composition in propulsion system testing environments suggests that this methodology is ready for use as a performance diagnostic for both ground testing and in-flight control.

Propulsion

Space Power and Propulsion
-- New, Clean, Highly Energetic Propellants Dynamics
-- Plasma Thruster Performance
-- Plume Characterization and Contamination

Air-Breathing Combustion
-- Supersonic Combustion
-- Advanced Fuel Composition and Use
-- Infrared Signature Reduction
-- Turbulent Reacting Flow Characteristics
-- Characterization of Fuel Droplets and Sprays

Research in this project addresses several propulsion technologies that have been identified as priority objectives in the Air Force New World Vistas 1995 study, including Hypersonics, Hypervelocity Dynamics, Low SFC Propulsion, Family of UAV, Micro Satellites, Distributed Functionality, Power Generation and Storage, and Controls. This research will develop computational design capability and efficient novel testing techniques to replace costly and lengthy trial-and error propulsion system development methods. These new cost-effective design approaches will lead to improved performance, reduced maintenance time and costs, lower observables, and extended lifetimes of propulsion systems on Air Force aircraft, missiles and spacecraft.

Upon request of the Arnold Engineering Development Center (AEDC), AFOSR extended research on plumes and signatures to include ultraviolet radiation. Enhanced efforts in soot reduction and control studies will increase engine performance and reduce aircraft signature and pollution. Research on turbulence-chemistry interactions in plumes seeks chemical and fluid dynamic control mechanisms for improving performance, fuel economy, and signature characteristics. Research continues to formulate new, clean, highly energetic propellants with proper chamber and mechanistic compatibility to satisfy environmental concerns.

Rocket combustion instability research is directed at the interactions among propellant combustion, rocket chamber dynamics, and heat transfer. Active feedback control techniques are being sought.

An important new research thrust for airbreathing engines (gas turbines and scramjets) is advanced fuel composition and combustion. Advanced engines may withstand higher operating temperatures by using fuel as a coolant. After heating to a supercritical thermodynamic state, the fuel will not behave like liquid or gas and may form solid residues which will clog vital fuel system components. Research addressing this problem includes fuel formulation, supercritical mixing, combustion, and the source of precombustion solids formation. New measurement techniques to characterize fuel-air mixing in both air-breathing and rocket chemical propulsion systems are being developed. Their techniques are essential to interpret system performance and to provide quantitative data to test the accuracy of computational design methods.

PROJECT 2310, ATMOSPHERIC SCIENCES

The atmospheric sciences project provides the fundamental research needed to understand the environment in which the Air Force operates. This improved understanding will lead to better precision-guided munitions, C^3I, surveillance, and spacecraft reliability. The Air Force requirement for night/in-weather operational capability is not achievable without this fundamental understanding of atmospheric processes. Atmospheric properties such as wind, clouds, precipitation, ionization, and optical/infrared transmissivity all affect Air Force system performance. AFOSR sponsored research includes extramural contracts/grants and basic research programs at Phillips Directorate. It emphasizes improved atmospheric prediction for enhanced tactical operations and atmospheric dynamics and impacts on communications and surveillance systems.

Atmospheric Sciences

Upper Atmospheric
-- Understanding the Ionosphere and Its Impact
-- Artificially Disturbed Ionosphere
-- Optical Atmosphere

Meteorology
-- Theater-Scale Prediction
-- Physics of Triggered Lightning
-- Mesoscale Processes

Upper atmospheric studies seek to improve C^3I, surveillance, and spacecraft reliability. Natural and artificial ionospheric disturbances, and optical phenomena can impact communications, degrade early warning systems, and decay spacecraft orbits. The Phillips Laboratory's Ionospheric Physics Division, and the Optical Environments Division, conduct most of this research which benefits operational customers such as Air Force Space Command and the Air Force Space Forecasting Center (AFSFC). A new explanation for strong lower wave hybrid turbulence, developed by researchers at Phillips Directorate, has the capability to predict regions of ionospheric disturbances.

Research in meteorology also focuses on the physics and dynamics of the lower atmosphere. The ultimate goal is to improve atmospheric prediction in support of tactical and strategic forces. The Phillips

Directorate of Atmospheric Sciences Division, (PL/GPA), conducts about one half of this research. Mesoscale weather prediction, boundary layer physics, cloud microphysics, and physics of triggered lightning comprise the main research interests. The Air Force's Weather System will take advantage of many discoveries in this subarea including recent efforts to integrate satellite data into mesoscale weather forecasting models. A tri-service program of research in atmospheric and space sciences is jointly planned through the Scientific Planning Group for Atmospheric and Space Sciences.

PROJECT 2311, SPACE SCIENCES

The Space Sciences project stimulates and supports basic research devoted to the Air Force mission of defending the United States through the control and exploitation of space. The Scientific Planning Group for Atmospheric and Space Sciences plans Tri-Service research programs in this area. The objective of space sciences is to understand the properties of the space arena in support of present and future Air Force operations. Research in space sciences provides the basic knowledge of the particles and electromagnetic fields in near-Earth space. The areas of space physics including solar dynamics, the interaction of particles and energy from the sun with the interplanetary medium and the Earth's magnetosphere. Solar radiation and charged atomic particles can damage and destroy Air Force spacecraft, disrupt the detection and tracking of missiles and satellites, distort communications, and interfere with surveillance operations. Space science research is critical to the development of future Air Weather Service models for the prediction of space weather and future Air Force space surveillance systems. This project strives to understand and quantify magnetospheric disturbances, such as geomagnetic storms, arising from solar disturbances.

These solar disturbances precipitate blackouts in satellite communication systems. Unimpeded surveillance and communications require prediction and mitigation of the effects of solar emissions. Research involves both experimental, analytical and theoretical studies based on data collected from Earth-based observatories, satellite sensors, laboratory simulations, and active space experiments that seek to control the space environment. The Space Sciences project performs basic research at the Geophysics Directorate of the Phillips Laboratory and at universities throughout the United States. The risk to space systems posed by energetic particles in the Earth's radiation belts continues to increase due to reliance on sophisticated and unhardened technologies. Theoretical work by Air Force physicists will emphasize the investigation of active methods to reduce the density of trapped particles in the Earth's magnetosphere.

Space Sciences

Space Physics
-- Magnetospheric Dynamics
-- Solar Disturbances
-- Active Space Experiments
-- Space Weather Prediction
-- Space Surveillance

PROJECT 2312, BIOLOGICAL SCIENCES

This project supports two major Air Force requirements: force readiness and health protection. Biological science research provides a fundamental understanding of the biological mechanisms regulating human performance, and the response of individuals and of the biological responses of individuals to toxic agents. This understanding is required to develop strategies to improve human performance and to protect both personnel and the environment from hazardous agents utilized in Air Force operations. Research in this project is planned through the Tri-Service Scientific Planning Groups for Biological Science, and Cognitive and Neurosciences.

Biological Sciences

- Bioenvironmental Sciences
  - -- Chemical Toxicology
  - -- Radiant Energy Bioeffects
  - -- Bioremediation
- Chronobiology and Neural Adaptation
  - -- Circadian Timing System
  - -- Aircrew Performance and Fatigue Prediction
  - -- Phase-Shifting the Biological Clock
- Biomimetic Sensors
  - --Electromagnetic Spectral Detection
  - --Polarization Imaging

Bioenvironmental sciences research seeks to understand fundamental mechanisms involved in assessing and predicting the human health and hazards associated with the use of Air Force chemicals, lasers and microwave radiation. Research in this area supports a number of Air Force customers, including the Air Force Center for Environmental Excellence (AFCEE), Air Combat Command (ACC), Air Mobility Command (AMC), Air Force Space Command (AFSPC), Air Force Research Laboratory (AFRL), Air Force Surgeon Generals Office (AFSGO), and the Air Force Safety Center. Studies focus on constructing predictive models to assess health risks. Ultimately, this research will contribute to the development of improved methods for the identification of environmentally safe materials and technologies during the early stages of their design and development. Early knowledge of potentially harmful bioeffects will better enable the Air Force to comply with environmental laws, protect human health, and avoid wasting time and resources on the scale up and manufacture of still more toxic materials. This research also provides a scientific base within the Air Force, enabling contributions to the risk assessment process for determining the environmental and health standards of Air Force-relevant materials and technologies. Research conducted in this area has strong dual-use applications in the fields of medicine, pharmaceuticals, biomolecular sensors, and health hazard risk assessment.

This year the bioenvironmental sciences program also includes a research effort in the biodegradation and detoxification of hazardous Air Force materials. This research examines the microbiological, biochemical and molecular mechanisms utilized by required microbes in the degradation of solvents, energetic compounds, and polymeric aircraft coatings. A mechanistic understanding of biodegradation will enable the Air Force to develop cost-effective and environmentally safe strategies for cleaning up contaminants, and to develop anti-degradative and anti-corrosive technologies for longer-life aircraft coatings. With possible dual-use applications in metabolic engineering and the recovery of usable manufacturing materials, this effort also supports Manufacturing Technology.

Chronobiology and Neural Adaptation. AFOSR supports basic research on the circadian timing system, the biology underlying fatigue including individual differences and performance prediction, the brain processes involved in regulating adaptation to changes-in-state, the neurobiology of attention and the biochemistry of stress. An understanding of these mechanisms will facilitate the development of pharmacological, photic and behavioral strategies for altering internal pacemaker function and ultimately alleviate the operational performance decrements associated with jet lag and night operations. Current experimental approaches include both human and animal behavior studies as well as biochemistry, molecular biology, electrophysiology, neurophysiology, and pharmacology. Data suggest that the circadian pacemaker contains a large population of autonomous, single-cell circadian oscillators and that synapses between these cells are neither necessary for this oscillation nor sufficient to synchronize them. Recent accomplishments include: 1) evidence that serotonin is an extremely important modulator of light input to the circadian pacemaker and probably can be used to modify light effects on the biological clock, thereby helping aircrew adapt to night operations, 2) a possible explanation of how temperature affects the biological clock, and 3) preliminary research results have just shown that moderate exercise three times a day helps improve sustained performance and suggests that regular exercise can turn night into day in so far as cognitive performance is concerned. Results of this research will improve operator performance during sustained operations by promoting the development of fatigue and alertness management tools. The key Air Force customers of this research are the Air Force Special Operations Command (AFSOC), Air Combat Command (ACC), Air Mobility Command (AMC), and the USAF Safety Center.

Biomimetic sensor research supports the Air Force need to enhance auditory and visual recognition for human situational awareness. Investigation of the physical mechanisms by which in vivo systems accept, process, and transmit visual and auditory information is currently underway. Research in this area is designed to integrate man made sensors with biological sensors or identify new biological materials that may act alone to improve sensory systems available to air crews engaged in the task of target detection and recognition.

PROJECT 2313, HUMAN PERFORMANCE

This project supports Air Force personnel readiness, and technology development for command and control and information systems, through a broad-based research program in Human Performance. Research in biological Sensory Systems contributes to technologies for image sensing and methods of information display best suited for human-system integration. Research in perception and cognition contributes to improved testing for personnel selection and classification, and the development of technologies to support both adaptive teams for Command and Control, and future workstations with embedded intelligent tutoring. This project is coordinated with other Services through the Cognitive and Neural Sciences panel of the tri-Service Scientific Planning Group.

In Sensory Systems, vision research supports the Air Force need to improve the effectiveness of visual displays, and camouflage, and to create novel systems for automated processing of image data. Researchers recently created and applied models of human contrast perception to problems of image quality measurement and camouflage. Models of retinal image processing derived from measures of neural circuitry in the retina are used to create novel integrated circuits for computer image processing.

Hearing research supports the Air Force need for secure error-free voice communication and improved human interface technologies that take advantage of automatic speech recognition and virtual environments. A model of acoustic signal encoding by vertebrates expresses a novel integrated circuit with potential use for hearing aids and related applications where signal shaping can increase intelligibility. A demonstrated neural network model of auditory localization can segment complex sound fields containing multiple sources. Cues to target location provided by novel 3-D audio devices improve visual search. These devices are now being tested for use by the ACC.

Human Performance

Sensory Systems
-- Human Image and Speech Processing
-- Biological Sensors
-- Multisensory Integration

Perception and Cognition
-- Cognitive Task Modeling
-- Individual Differences Prediction
-- Human-Machine Interaction
-- Intelligent Tutoring Strategies
-- Team Resource Management

An understanding of multisensory integration is critical for the development of uninhabited air vehicles (UAVs), and is required to make the dynamic aviation environment safe by reducing the human sensory mismatches that result in pilot disorientation in aircraft accidents. The focus is on the integration of visual, vestibular, kinesthetic and proprioceptive information processing. Experimental and theoretical approaches involve the simultaneous examination of visual search patterns, the speed and accuracy of complex joint movements, and the underlying patterns of control necessary to assure safe flight. The USAF Safety Center and Air Combat Command are the key customers of this research.

Perceptual and Cognitive sciences support Air Force needs for selection and classification of personnel, improved instruction and training, and expert performance in an environment of increasing cognitive workload. Specifically, research on cognitive and psychomotor abilities seeks to develop tests of those abilities for improved computerized selection and classification batteries. This research, combined with studies of individual variation in ability, supports the development of technologies for evaluation of necessary job skills and development of computerized aiding and intelligent tutoring systems based on human ability. Research on human-machine interfaces supports development of novel technologies for human interface, such as interfaces to virtual environments, in support of Air Force missions in unmanned air vehicles and in command and control. Research on intelligent tutoring systems supports technology goals of the Air Force to develop systems to implement both training and operational performance on the same equipment. Research on team resource management takes advantage of synthetic task environments, laboratory versions of real-world job tasks, to study and model the several factors that affect performance of command and control teams. These factors include: human interface, embedded training, communication patterns, and workload protocols.

The primary customers of research in Perception and Cognition, the Air Force Research Laboratory and the Air Education and Training Command (AETC), have benefited from recent findings of this program. Specifically, new neurometric techniques for cognitive workload measurement have been developed for use in laboratory experiments on cognitive workload and have been reduced to practice for evaluation in more applied contexts. In addition, a new image processing algorithm has been discovered, based on human visual processes, that offers increased precision in the specification of corners and edges of objects in visual imagery. This algorithm has already been incorporated into laser ranging devices for reverse engineering for manufacturing.

PROJECT 4113, SCIENCE AND ENGINEERING EDUCATION PROGRAMS

In addition to the research conducted under scientific projects, AFOSR supports programs to stimulate scientific and engineering education; and to increase the interaction between the broader research community and the Air Force laboratory. The programs increase the number of U.S. citizens with advanced degrees in science and engineering--key contributors to industrial competitiveness and military security. Full participation by minorities is an integral objective of all our programs. AFOSR uses Office of the Secretary of Defense (OSD) and Air Force funds to support the Science and Engineering Education programs discussed in this section. This is a DoD-wide program to strengthen the ability of universities to conduct research and educate scientists and engineers in technologies important to national defense. Each Air Force research program may include funds for graduate fellowships or grants, research instrumentation, and exchanges of scientists and engineers with DoD laboratories. Fellowships and grants increase the number of graduate students in science and engineering. Upgrading university instrumentation enhances universities' research and education capabilities, as well as scientific exchanges. The exchanges also increase contacts among universities, industry, and DoD laboratories, maximizing the contributions of defense research to the nation's military and economic security.

Summer Faculty Research Program (SFRP): The SFRP stimulates new relationships with university science and engineering faculty and their professional peers in the Air Force; enhances the research interests and capabilities of scientific and engineering educators in areas of Air Force interest; and develops the basis for continuing research of Air Force interest at the faculty member's institution. More than 150 university faculty will be selected to conduct research at Air Force laboratories for up to twelve weeks in FY 98. Upon completion, approximately 60 mini grants (up to $25K each) will be awarded in FY 98 to continue promising SFRP research efforts at the institution of the faculty member.

Graduate Student Research Program (GSRP): GSRP is an adjunct to the SFRP. It permits graduate students to participate in research at the Air Force laboratory; stimulates professional association among graduate students, their supervising professors, and professional peers in the Air Force; furthers research objectives of the Air Force; and exposes graduate students to potential thesis topics in areas of Air Force interest. In FY 98, more than 100 graduate students will be selected to perform research for up to twelve weeks during the summer at Air Force laboratories.

University Resident Research Program (URRP): The URRP stimulates research cooperation between Air Force laboratories and institutions of higher education. Under the URRP, faculty members are brought into Air Force laboratory to conduct research for one year after which they return to their university with a broadened awareness of Air Force research needs and operations. Extension for a second year of residency is possible. For FY 97, twenty-four URRP slots are allocated to the laboratories.

USAF National Research Council (NRC) Resident Research Associateship Program: This program provides postdoctoral and senior scientists and engineers opportunities to conduct research compatible with the research interests of selected sponsoring Air Force laboratories.

The postdoctoral program is available to U.S. citizens and permanent residents, and focuses on developing America's most promising new PhD's. The senior associate positions, intended for internationally renowned researchers, are open to both U.S. and foreign citizens. Applicants must apply to the NRC and pass an NRC panel review to be considered for an award. Approximately 70 researchers will receive awards in FY 98.

National Defense Science and Engineering Graduate Fellowship Program (NDSEG): AFOSR participates in the National Defense Science and Engineering Graduate (NDSEG) Fellowship Program with the Army Research Office, the Office of Naval Research, and the Defense Advanced Research Projects Agency. The purpose of the program is to increase the number of U.S. citizens trained in science and engineering of military importance. The Air force will award approximately 25 three year fellowships in FY 98.

GLOSSARY

ABL	Airborne Laser
ACC	Air Combat Command
AEDC	Arnold Engineering Development Center
AETC	Air Education and Training Command
AFCEE	Air Force Center for Environmental Excellence
AFOSR	Air Force Office of Scientific Research
AFOTEC	Air Force Operational Test and Evaluation Center
AFRL	Air Force Research Laboratory
AFSFC	Air Force Space Forecasting Center
AFSGO	Air Force Surgeon Generals Office
AFSOC	Air Force Special Operations Command
AFSPC	Air Force Space Command
AMC	Air Mobility Command
ASC	Aeronautical Systems Center
ASPIRE	AFOSR Scholars Program Integrating Research and Education
ATR	Automatic Target Recognition
BMDO	Ballistic Missile Defense Organization
C^3I	Command, Control, Communications and Intelligence
CEM	Computational Electromagnetics
CFD	Computational Fluid Dynamics
CMC	Ceramic Matrix Composite
DARPA	Defense Advanced Research Projects Agency
DCOR	Defense Committee on Research
DRS	Defense Research Sciences
EPA	Environmental Protection Agency
FAST	Future Aerospace Science and Technology
FFRDC	Federally Funding Research and Development Center
FY	Fiscal Year
G-LOC	Gravity-Loss of Consciousness
GEO	Geosynchronous
GSRP	Graduate Student Research Program
HBCU	Historically Black Colleges and Universities
HEDM	High Energy-Density Matter
HPM	High Power Microwave
IHPTET	Integrated High Performance Turbine Engine Technology
INS	Inertial Navigation System
IR&D	Independent Research and Development
JTAGG	Joint Turbine Advanced Gas Generator
LEO	Low Earth Orbit
LES	Large-Eddy Simulation
MEM	microelectromechanical
MI	Minority Institutions
MIT	Massachusetts Institute of Technology
MURI	Multidisciplinary University Research Initiative
NDE	Nondestructive Evaluation
NDSEG	National Defense Science & Engineering Graduate
NRC	National Research Council
NWV	New World Vistas
OSD	Office of the Secretary of Defense
P&W	Pratt and Whitney
PRET	Partnerships for Research Excellence and Transition
RCS	Radar Cross Section
S&T	Science and Technology
SAR	Synthetic Aperture Radar
SBIR	Small Business Innovation Research
SFRP	Summer Faculty Research Program
SMC	Space and Missile Systems Center
SPGs	Scientific Planning Groups
SPO	System Program Office
STTR	Small Business Technology Transfer
TAP	Technology Area Plan
TARA	Technology Area Review and Assessment
TEO	Technology Executive Officer
TMI	Third Millennium Initiatives
TMP	Technology Master Process
TTO	Technology Transition Office
UAV	Unmanned Aerial Vehicles
URI	University Research Initiative
URRP	University Resident Research Program

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